**ACCELERATOR DIVISION ADMINISTRATIVE PROCEDURE**

**ADAP-11-0003**

**Approved Accelerator Beam Intensity Operating Limits**

**RESPONSIBLE DEPARTMENT: ES&H RPS**

**PREPARED BY**   **DATE**

**Radiation Physics Science Department Head**

**REVIEWED BY**   **DATE**

**Radiation Physics Operations Department Head**

**REVIEWED BY**   **DATE**

**Accelerator Division Operations Department Head**

**APPROVED BY**   **DATE**

**Accelerator Division Head**

**REVISION NO.**   **REVISION ISSUE DATE**

Revision History

|  |  |  |
| --- | --- | --- |
| Author | Description of Change | Revision No. & Date |
| Maddie Schoell | Added Reference 33 for Muon Camps. Updated “Area” column titles for Muon Campus areas for clarity. Operating Limits did not change. | Revision 10  2/10/2020 |
| Maddie Schoell | Initial use of Revision History table | 12/13/2018 |

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# PURPOSE AND SCOPE

In accordance with the DOE Accelerator Safety Order, DOE O 420.2C, and as flowed down through the Fermilab Director’s Policies, the Fermilab Environment Safety and Health Manual (FESHM) including the Fermilab Radiological Control Manual (FRCM), this document defines the approved accelerator beam intensity operating limits derived from the various radiological shielding assessments or other safety documents such as the Fermilab Safety Assessment Document (SAD).

The table in Section 2.0 specifies the beam intensity limitations for each section of the Fermilab accelerator complex. The shielding assessments conducted for each beamline or experimental area with respect to the FRCM limits found that continuous operation at an intensity defined in the Operating Intensity Limits along with the stated beam energy is safe and defines the normal Beam Permit operating limits.

The Basis listed in the table identifies what limits the beam intensity for each area. The term “Overburden” is used in the table when the Operating Intensity is limited by the shielding surrounding the beamline enclosure. The term "Absorber" is used when the intensity is limited by the thermal and/or mechanical properties of a specified beam absorber. These intensity limits are specified in particles per hour since the concern here is prompt radiation exposures from beam operations. The terms “Groundwater”, "Surface Water", and “Air Activation” are used when the intensity is limited by the number of particles that, due to activation of air or unprotected soil surrounding the enclosures, result in radioactivity in the air, groundwater, or surface water. Air, groundwater, and surface water limits are cumulative effects and are expressed in particles per year.

# BEAM INTENSITY OPERATING LIMITS

| **Area** | **Operating Intensity Limit** | **Beam Energy** | **Basis** |
| --- | --- | --- | --- |
| Linac | 3.54E17 protons/hour | 400 MeV | Overburden 1 |
| Linac to NIF | 6.70E17 protons/hour | 66 MeV | Overburden 2 |
| Linac Absorber #1 | 6.40E20 protons/year | 400 MeV | Groundwater 3 |
| Linac Absorber #2 | 6.40E20 protons/year | 400 MeV | Groundwater 3 |
| MuCool Test Area to Emittance Absorber (Emittance Mode) | 9.60E15 protons/hour | 400 MeV | Overburden 4 |
| MuCool Test Area to Final Beam Absorber (Experiment Mode) | 9.60E14 protons/hour | 400 MeV | Overburden 4 |
| MuCool Test Area Final Beam Absorber | 2.35E18 protons/year | 400 MeV | Air Activation 5 |
| Booster to  MI-8 Line Cell 803 | 2.70E17 protons/hour | 8 GeV | Overburden 6 |
| Booster 8 GeV Absorber | 6.80E18 protons/year | 8 GeV | Surface Water 7 |
| MI-8 Line from  Cell 803 to Cell 850 | 2.84E17 protons/hour | 8 GeV | Overburden 8 |
| Booster Neutrino Beamline from MI-8 Line Cell 850 | 1.62E17 protons/hour | 8 GeV | Overburden 8 |
| Booster Neutrino Beam Target Station | 7.50E20 protons/year | 8 GeV | Air Activation 9 |
| Main Injector | 2.93E17 protons/hour | 8 GeV | Overburden 10 |
| Main Injector | 2.93E17 protons/hour | 120 GeV | Overburden 10 |
| Main Injector | 2.34E17 protons/hour | 150 GeV | Overburden 10 |
| MI-40 Abort | 1.56E19 protons/year | 8, 120 &  150 GeV | Surface Water 11 |
| Recycler | 2.25E17 protons/hour | 8 GeV | Overburden 12 |
| NuMI | 2.25E17 protons/hour | 120 GeV | Overburden 13 |
| NuMI Target Station | 1.24E21 protons/year | 120 GeV | Surface Water 14 |
| P1-P2 Lines Muon Campus Operations Only | 6.50E16 protons/hour | 8 GeV | Overburden 15 |
| P1-P2 Lines Muon Campus and  Switchyard Operations | 5.41E16 protons/hour | 8 GeV | Overburden 16 |
| P1-P2 Lines Switchyard Operations | 1.25E15 protons/hour | 120 GeV | Overburden 16 |
| Muon Campus  M1-M3 Lines through Delivery Ring to Diagnostic Absorber | 3.60E13 protons/hour | 8 GeV | Overburden 17, 33 |
| Muon Campus  M1 Line to AP0 Target to  g-2 Storage Ring | 4.32E16 protons/hour | 8 GeV | Overburden 17 |
| AP0 Target Station | 3.20E20 protons/year | 120 GeV | Surface Water 18 |
| Delivery Ring Cleanup Absorber | 9.49E18 protons/year | 8 GeV | Surface Water 19 |
| P3 Line to Switchyard Absorber | 6.00E14 protons/hour | 120 GeV | Overburden 20 |
| P3 Line to M01 Target Train (Meson Primary) | 1.68E14 protons/hour | 120 GeV | Overburden 20 |
| P3 Line to Meson Test | 1.20E13 protons/hour | 120 GeV | Overburden 20, 21 |
| Switchyard Absorber | 2.98E17 protons/year | 120 GeV | Groundwater 22 |
| M01 Target Train Absorber | 7.94E17 protons/year | 120 GeV | Groundwater 22 |
| M02 Absorber | 1.74E17 protons/year | 120 GeV | Surface Water 22 |
| M03 Pinhole Collimator | 1.74E17 protons/year | 120 GeV | Surface Water 22 |
| P3 Line to Meson Center | 1.02E12 protons/hour | 120 GeV | Overburden 23 |
| MC6 Target Pile | 5.26E16 protons/year | 120 GeV | Surface Water 24 |
| P3 Line to  Neutrino Muon | 6.00E14 protons/hour | 120 GeV | Overburden 25 |
| NM3 Target Station | 5.26E18 protons/year | 120 GeV | Surface Water 26 |
| FAST Beam to  Low Energy Absorber | 1.96E17 electrons/hour | 55 MeV | Absorber 27 |
| FAST Low Energy Absorber | 6.65E20 electrons/year | 55 MeV | Surface Water 28 |
| FAST Beam to  High Energy Absorber | 3.37E18 electrons/hour | 300 MeV | Overburden 29 |
| FAST High Energy Absorber | 3.40E21 electrons/year | 300 MeV | Surface Water 30 |
| FAST Injection  into IOTA Ring | 3.60E13 electrons/hour | 150 MeV | Overburden 31 |
| IOTA Ring Circulating Beam | 2.00E10 electrons | 150 MeV | Overburden 32 |

# DISTRIBUTION

An electronic controlled copy of this procedure is maintained on the AD ESH website at:

<https://ad-esh.fnal.gov/ad_adap.html>.

An uncontrolled copy is provided to the Fermi Site Office.

# REFERENCES

1. ***Completion of the Linac Shielding Assessment and Verification of Operation at Full Intensity***, memo from G. Dugan to D. Cossairt, June 28, 1991, on pages 5‑6 of the***Linac Shielding Assessment***, October 18, 1991. Operation at 400 MeV is documented in ***Radiation Shielding Assessment of the Linac High Energy Enclosure Following the 1993 Upgrade Installation and Low Intensity Commissioning***, C. Schmidt and T. Kroc, September 21, 1993.
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3. ***Linac Momentum Beam Dump Vacuum***, L. Allen *et al.*, November 2011,   
   Beams‑doc‑4095, page 27. The straight-ahead dump is structurally similar to the momentum dump, so the same intensity limit is used for both.
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6. ***Booster Shielding Assessment***, January 17, 2017, page 5.
7. ***Booster Shielding Assessment***, January 17, 2017, page 9.
8. ***8 GeV Beam Line and MiniBooNE Beam Line Nova-Era Operational Limits***, M. Gerardi, March 10, 2010, post-assessment memo in ***Shielding Assessment Document for the 8 GeV Fixed Target Facility***, C. Moore, June 20, 2002.
9. ***Addendum to the MiniBooNE Target Station Shielding Assessment***, M. Gerardi *et al.*, June 18, 2004, page 3.
10. ***Main Injector 1500 kW Incremental Shielding Assessment***, W. S. Higgins *et al.*, May 23, 2018, page 3. Note that although the 8 GeV intensity limit could be substantially higher if it were scaled with beam energy, there is no operational need for a higher 8 GeV intensity; therefore, the 8 GeV intensity limit has been set equal to the 120 GeV intensity limit.
11. ***Main Injector 1500 kW Incremental Shielding Assessment***, W. S. Higgins *et al.*, May 23, 2018, page 6.
12. ***Recycler Ring Incremental Shielding Assessment 2.25x1017 Protons/Hour***, W. Schmitt *et al.*, October 3, 2012, page 2.
13. ***Addendum to the NuMI Beam Line Shielding Assessment for 1 MW Operation of NOvA Experiment***, K. Vaziri *et al.*, July 17, 2018, page 1.
14. ***Addendum to the NuMI Beam Line Shielding Assessment for 1 MW Operation of NOvA Experiment***, K. Vaziri *et al.*, July 17, 2018, Table 2, page 7.
15. ***P1 and P2 Beamline Incremental Shielding Assessment***, M. Geelhoed, February 9, 2016, page 4.
16. ***P1-P2 Beamline Operating Limits***, W. Schmitt, October 20, 2016, post-assessment memo in ***P1 and P2 Beamline Incremental Shielding Assessment***, M. Geelhoed, February 9, 2016.
17. ***Muon g-2 Shielding Assessment***, A. Leveling, February 7, 2017, page 5.
18. ***AP0 Target Station Review Committee Report***, C. Hojvat *et al.*, June 9, 1997, Section F, page 10.
19. ***Delivery Ring Cleanup Abort Design***, A. Leveling, November 3, 2015,   
    Beams‑doc‑5178, Table 2, page 22.
20. ***Further Explanation of Assessed Beam Intensity for P3 to SY Absorber***, M. Vincent, November 14, 2017, post-assessment memo in ***P3 to Switchyard Absorber Incremental Shielding Assessment***, M. Geelhoed *et al.*, September 20, 2017.
21. ***Meson Test Operating Limits Based on Operational Experience***, G. Lauten, October 22, 2015, post-assessment memo in ***2003 Shielding Assessment for the Switchyard 120 Project***, C. Brown *et al.*, April 8, 2003.
22. ***2003 Shielding Assessment for the Switchyard 120 Project***, C. Brown *et al.*, April 8, 2003, pages 9‑10.
23. ***MC7 NOvA beam intensity limit***,W. Schmitt, November 20, 2018, post-assessment memo in ***Addendum to the SY 120 Shielding Assessment for the Continued Operation of the Meson Center Beam Line***, T. Kobilarcik and W. Schmitt, November 25, 2013.
24. ***Addendum to the SY 120 Shielding Assessment for the Continued Operation of the Meson Center Beam Line***, T. Kobilarcik and W. Schmitt, November 25, 2013, pages 8‑9.
25. ***Neutrino Muon Beamline Shielding Assessment***, T. Kobilarcik and M. Geelhoed, February 24, 2012, page 4.
26. ***Neutrino Muon Beamline Shielding Assessment***, T. Kobilarcik and M. Geelhoed, February 24, 2012, page 9.
27. ***Shielding Assessment for the Advanced Superconducting Test Accelerator (ASTA) Injector***, M. Church *et al.*, December 12, 2014, page 5.
28. ***Shielding Assessment for the Advanced Superconducting Test Accelerator (ASTA) Injector***, M. Church *et al.*, December 12, 2014, pages 12‑13.
29. ***Shielding Assessment for IOTA/FAST Electron Injector at 300 MeV***, D. Broemmelsiek and I. Rakhno, August 23, 2017, page 14.
30. ***Shielding Assessment for IOTA/FAST Electron Injector at 300 MeV***, D. Broemmelsiek and I. Rakhno, August 23, 2017, page 22.
31. ***Fermi National Accelerator Laboratory Safety Assessment Document, Revision 16, Section IV, Chapter IV‑3: Fermilab Accelerator Science & Technology (IOTA/FAST) Electron Injector***, E. Harms *et al.*, April 23, 2018, ESHQ‑doc‑1066, page 7.
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33. ***Muon Campus Shielding Assessment for 8 GeV Beam Transmission to the Diagnostic Absorber***, A. Leveling, February 5, 2020, page 5.